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East Malling.

New York Agricultural Experiment Station.

GENEVA, N. Y.

DEAD-ARM DISEASE OF GRAPES.

DONALD REDDICK.

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liminary report on a destructive disease of grapes, entitled Necrosis of the Grape Vine. At the time of publication of that bulletin it was realized that there were many points yet to be studied. Among these should be mentioned, first of all, the absence of inoculation experiments which would prove absolutely that the fungus found constantly associated with the disease was really the primary cause of it and not a secondary factor incidental to some other disorder. A more extended survey of the distribution of the disease in the vineyard regions of the State and a more intensive study of its occurrence in individual vineyards seemed important. Careful observations and experiments were necessary on the method by which the disease spreads. This seemed particularly true with respect to the possibility of spread of the disease through affected nursery stock. Finally, control experiments based upon the above findings were of utmost practical importance.

Through opportunity to work at the vineyard laboratory of the Station during the summers of 1909 and 1910 a number of these points have been cleared up and a satisfactory report of progress of the investigations can now be made. Although this report is intended primarily to supplement and extend the work reported in the Cornell bulletin, certain portions of the information recorded there is repeated inasmuch as the edition of that bulletin is exhausted.

THE DISEASE.

NAME.

The name most commonly applied to this disease is dead-arm or side-arm disease. The writer undertook to introduce the name necrosis, which still appeals to him as a good name for this type of disease, but unfortunately he was not aware, until the fact was pointed out, in 1911, by Dr. Shear, of the United States Department of Agriculture, that this name had already been used by Cavara (1897) to designate a bacterial disease of the grape occurring in Europe, said to be caused by *Bacillus vitivorus*. It therefore seems advisable to go back to the well-established name of dead-arm disease.

OCCURRENCE.

The disease occurs on practically every variety of the grape grown commercially in the State. Naturally it is most frequently met with

on the more important commercial varieties. Delaware seems to have a certain amount of resistance, at least the disease has rarely been found on that variety. The variety Pocklington seems to be particularly susceptible, but as this variety is not grown extensively, data on this point are difficult to obtain.

DISTRIBUTION.

So far as the writer's observations go, no district in the State is free from the disease, nor does there seem to be any great difference in the prevalence of the disease in the different districts. The writer has rarely visited a vineyard in the State in which at least occasional diseased vines could not be found. Perhaps the least of the disease is to be found in the Keuka Lake region. This is only a general impression as no accurate estimates of percentages of diseased vines have ever been made in this section.

The observations of Shear (1911) extend the known distribution of the disease to practically all the vine-growing sections of the eastern United States. Lately Bubák (1911) has reported a vine disease occurring in Hungary the cause of which is described as a fungus closely related to the causal organism of the dead-arm disease. Since no such disease has been reported either from France or Germany it seems quite evident that the disease is indigenous to America and apparently confined to it at the present time.

LOSSES.

The insidious nature of this disease makes a determination of its extent and destructiveness almost impossible. One may mark 1 per ct., 2 per ct., or occasionally 5 per ct. of diseased vines in a vineyard at a single inspection. Sometimes as many more can be marked the following year. How long this might continue remains to be seen.

The loss, of course, is considerable. Besides the dead vines there are many others declining in vitality which each year bear fewer and fewer pounds of grapes until finally they die or are removed.

SYMPTOMS.

(a) The dead arm is the most strikingly obvious symptom of the disease. Fig. 2 (Plate II). Almost as frequently the entire vine dies, in which case suckers usually spring up about the base.

(b) Another striking symptom, but visible only in June and early July, is the peculiar yellow coloration of the foliage and the dwarfing, crimping, and curling of the leaves. Fig. 1 (Plate I). As the season advances the yellow color usually disappears, but the small crimped leaves still persist. The grower is sometimes deluded into believing that his vines have grown out of the disease. Careful examination the next year, however, will show that the vine is either dead or in a much more weakened condition.

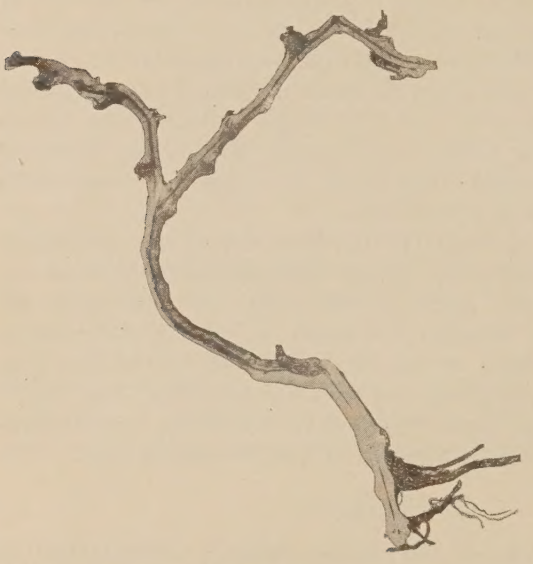


FIG. 3.—LONGITUDINAL SECTION OF TRUNK AND ARM OF VINE SHOWN IN PLATE II.
(Position of arms reversed.)

(c) Vines are apt to die at any time of the year although most of them seem to die in the winter. Presumably their feeble growth of the preceding summer makes them very susceptible to injury by frost and cold. Fig. 3. It is not unusual, however, to find a vine wilting in midsummer.

(d) In certain instances one may find peculiar longitudinal ribbed excrescences on the trunk or arm. The excrescence is not tuberculate as in the case of crown gall, and it does not possess the fleshy consistency of a crown gall tumor. Nor does the excrescence have the appearance or consistency of the hard tuberculous outgrowth which follows winter injury.[2]

[2] Particular mention is made of these facts because they correct certain mistakes of the former bulletin. The vine shown in Cornell Bulletin 263, fig. 45, is attacked by crown gall as well as dead arm, and the lesions shown in this figure and in figure 46 are caused by the crown gall organism, *B. tumefaciens*. The lesion shown in figure 47 is probably of similar origin, as it came from a vineyard in which practically all the vines are infected. When in the vineyard on July 21, 1909, very evident lesions of the dead-arm disease were found on two shoots.

(e) A dry rot in the heart of the trunk and usually extending to the margin is more or less characteristic. (Fig. 4.)

FIG. 4.—CROSS SECTIONS OF DISEASED NIAGARA TRUNKS SHOWING CHARACTERISTIC NECROTIC EFFECT.

(f) The small reddish brown or black spots on the green shoots, petioles, peduncles, and leaf veins are very characteristic. Sometimes they are deep and the shoot shows narrow V-shaped slits; at other times the spots are more superficial but are so numerous as to make a continuous diseased area for some distance on the shoot. In very severe cases the lesions are deeper and the V-shaped slits mentioned above extend for some distance, usually from one to three inches, up and down the shoot. Fig. 5 (Plate III). These lesions are discernible the following spring as reddish elevations, or as a noticeable longitudinal cracking or stringing of the fibres.

(g) The occurrence of the disease on ripe or nearly ripened berries has been found repeatedly on Niagara grapes at Romulus, N. Y., by Mr. C. T. Gregory (1913). The disease is scarcely distinguishable from black rot except on very careful examination. Usually it is necessary to use the microscope to confirm a diagnosis with any degree of certainty. The berry shrivels (Fig. 6—Plate III) to a mummy as in the case of black rot but has a slightly more grayish appearance and the pustules which occur so thickly over the surface of a black-rot berry are more scattered in the case of this rot.

ETIOLOGY.

The cause of this disease is a fungous parasite technically known as *Cryptosporella viticola* Shear. The fungus was apparently first

Isolations made from an old arm near the first wire of the vine shown in figure 45 and from various places in and above the lesion shown in figure 47 gave numerous pure cultures of the causal organism of dead arm. The vine in figure 45 has been visited every year since the photograph was taken. In July, 1910, some of the shoots showed evident lesions of the dead-arm fungus. In 1912 the vine bore a good crop of fruit although the lesions of crown gall were about as abundant as in the photograph.

EXPLANATION OF PLATES AND FIGURES.

FIG. 1. (PLATE I) — CONCORD VINE IN LAST STAGES OF DEAD-ARM DISEASE.
One arm apparently missing for several years.
(No. 3227. Fredonia, N. Y., June 21, 1909.)

FIG. 2. (PLATE II) — CHARACTERISTIC APPEARANCE OF VINE AFFECTED WITH DEAD-ARM DISEASE.
The small blanched and crinkled leaves on the cane at the left are typical. Some leaves on arm at right not full size and some blanched about the margins. Arm at right would have died during the summer or succeeding winter. A longitudinal section of trunk and arms is shown in Fig. 3.
(No. 3226. Fredonia, N. Y. Photograph made June 24, 1909.)

FIG. 3. LONGITUDINAL SECTION OF TRUNK AND ARM OF VINE SHOWN IN PLATE II.
Position of arms reversed. Trunk diseased for several years as shown by extent of diseased (dark) area. Relatively small amount of healthy conducting tissue of interest as is fact that tissue below surface of the ground is healthy. (Figure on p. 466.)

FIG. 4. CROSS SECTIONS OF DISEASED NIAGARA TRUNK SHOWING CHARACTERISTIC NECROTIC EFFECT. (Figure on page 467.)
(Natural size. Photograph made Oct. 26, 1908.)

FIG. 5. (PLATE III) — LESIONS OF DEAD-ARM FUNGUS ON SHOOTS.
Probably from infection of May 28, 1909. Various degrees of infection shown. Shoot at bottom infected at so many points that lesions fused to form continuous blackened area. Longitudinal splitting evident in some cases.
(No. 3240. Worden. Romulus, N. Y. Photograph made Aug. 2, 1909, by C. N. Jensen.)

FIG. 6. (PLATE III) — ROT OF BERRIES CAUSED BY DEAD-ARM FUNGUS.
Earlier stages (upper left in plate) center about lenticels, differing from black rot in that respect as well as in general appearance. Later stages can scarcely be distinguished from black rot except by microscopic examination.
(No. 6118. Niagara. Romulus, N. Y. Photographs made Oct. 8, 1912, by C. T. Gregory.)

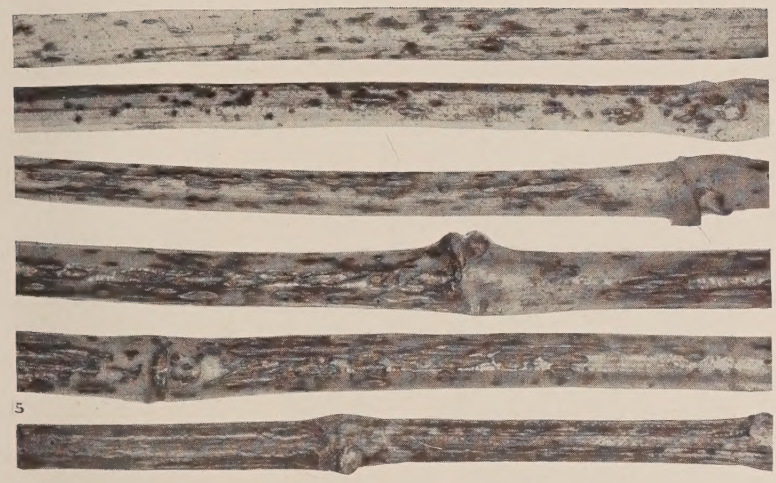
FIG. 7. (PLATE III) — LESIONS OF ANTHRACNOSE DISEASE ON SHOOTS AND BERRIES.
Anthracnose and the dead-arm disease confused by some although lesions are very different. Most conspicuous difference in case of anthracnose, which, on shoots, is usually noticeably elevated.
(Vergennes. Portland, N. Y. Photographs made July 24, 1909.)

FIG. 8. PERITHECIAL STROMATA OF *Cryptosporella viticola*.
(Found and illustrated by Shear.)

(*Explanations continued on page following plates.*)

PLATE I.— CONCORD VINE IN LAST STAGES OF DEAD-ARM DISEASE.

PLATE II.— CHARACTERISTIC APPEARANCE OF VINE AFFECTED WITH DEAD-ARM DISEASE.



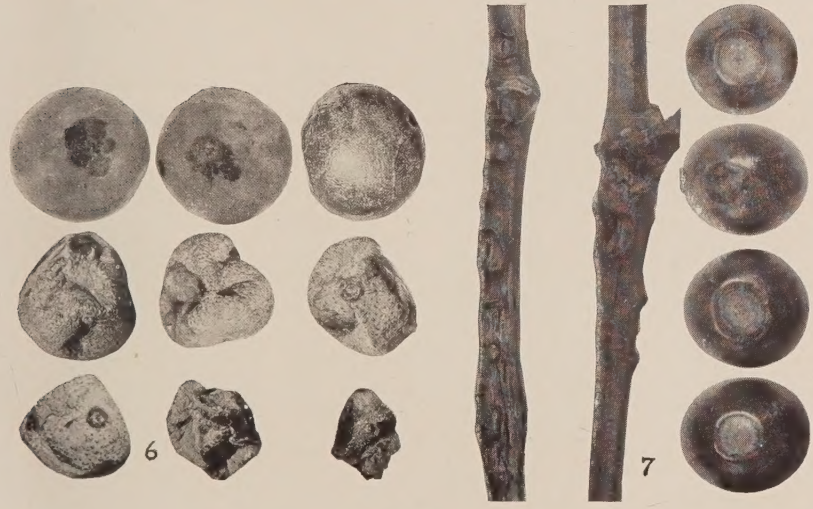
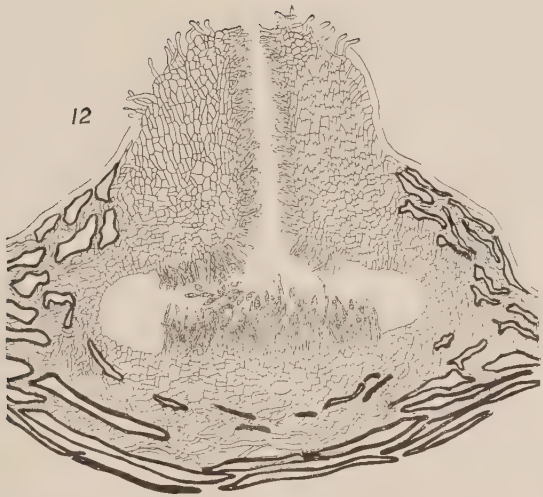
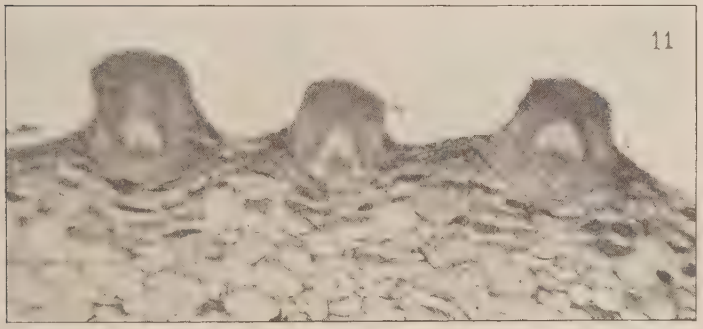


PLATE III

5, Lesions of dead-arm fungus on shoots.
6, Rot of berries caused by dead-arm fungus
7, Lesions of anthracnose disease on berries and shoots.

PLATE IV.— PYCNIDIA OF *C. viticola*





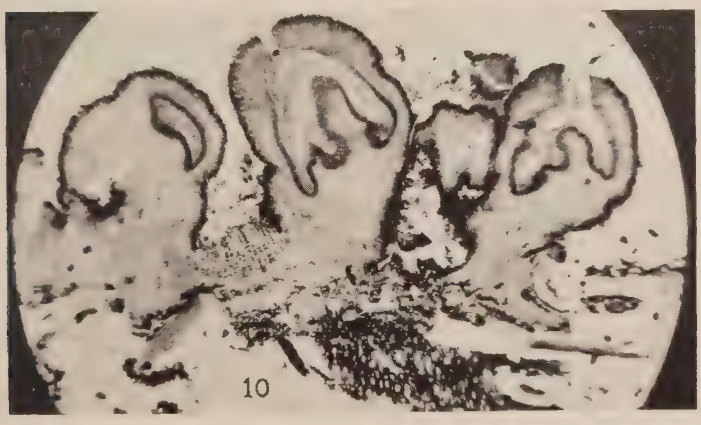


PLATE V.

(See page 469 for explanation.)

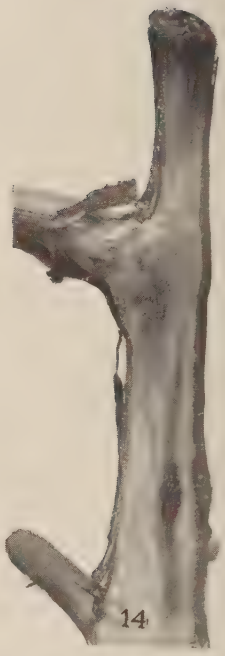


PLATE VI.— ARTIFICIAL INFECTION ON TRUNK (13) AND CANE (14) OF WORDEN VINE.

FIG. 9. (PLATE IV) — PYCNIDIA OF *Cryptosporella viticola*.
A. On Concord cane.
(No. 3232. Lamberton, N. Y. Aug. 10, 1909.)
B. On Niagara trunk.
(No. 3225. Romulus, N. Y. June 9, 1909.)
C. On Worden cutting, causing its death.
(Twice natural size. Photograph made July 10, 1910.)
D. On Concord arm.
(No. 2983. Westfield, N. Y. Collected and photographed May 1, 1904, by H. H. Whetzel.)

FIG. 10. (PLATE V) — PHOTOMICROGRAPH OF PYCNIDIA ON TRUNK OF CONCORD VINE SHOWING RELATIVE POSITION.
The cavity in such pycnidia is usually much convoluted.

FIG. 11. (PLATE V) — PHOTOMICROGRAPH OF THREE PYCNIDIA IN A ROTTEN BERRY SHOWING RELATIVE POSITION.
Pycnidia on the fruit are usually simple.

FIG. 12. (PLATE V) — DRAWING OF CROSS-SECTION OF SIMPLE PYCNIDIUM FROM FRUIT OF NIAGARA GRAPE.
Spore-bearing area only partially filled in. Both pycnospores and scolecospores are shown.
(Outlined with aid of camera lucida from stained section, by C. T. Gregory.)

FIG. 13. (PLATE VI) — ARTIFICIAL INFECTION ON TRUNK OF WORDEN VINE.
Inoculation made July 12, 1909. Point of inoculation may be seen near margin.
Infection has occurred but fungus has not spread rapidly
(No. 3229. Photograph made July 19, 1910.)

FIG. 14. (PLATE VI) — ARTIFICIAL INFECTION ON CANE OF WORDEN VINE.
Inoculation made July 9, 1909.
(No. 3216. Photograph made Sept. 24, 1910.)

described by the writer (1909) as one new to science. It was found and described only in its imperfect stage and was called *Fusicoccum viticolum*. Since that time Shear (1911) has found the ascosporic or so-called perfect stage. He finds it to be one of the genus Cryptosporella and calls it *C. viticola*.

LIFE HISTORY OF FUNGUS.

Perithecia.— The Cryptosporella stage of the fungus has been reported by Shear from Michigan, Virginia, and New Jersey. This author states further, p. 118, that it is doubtful whether the ascosporic stage plays any important part in perpetuating the fungus. The writer had made diligent search for it in many of the vineyards of the State, and had attempted to develop it in culture, but up to the present time has not succeeded in finding it.

The perithecia of the fungus, as described by Shear, are buried in a stroma of fungous and host tissue occurring beneath the cortex. The cortex is lifted up but the stroma does not become exposed as in the case of the pycnidia. The perithecium is globose, thin-walled, and provided with a short, smooth beak which extends through and slightly beyond the cortex (Fig. 8). Within the perithecium are numerous cylindrical asci measuring 60 to 72 by 7 to 8 μ, each containing eight ascospores. The ascospores are subelliptical, colorless, one-celled and measure 11 to 15 by 4 to 6 μ. Between the asci are slender, septate, sterile threads known as paraphyses.

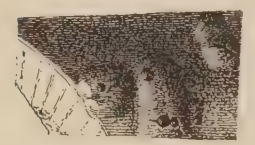


FIG. 8.—PERITHECIAL STROMATA OF *C. viticola*. (After Shear.)

The fact that this stage of the fungus has never been found in the State although diligent search has been made for it, both before and since the appearance of Dr. Shear's paper, makes it reasonably certain that the perithecial stage of the fungus plays no important rôle in the dissemination or perpetuation of the fungus with us.

Pycnidia.— This stage of the fungus is very abundant. It commonly occurs in the bark of the previous season or of two seasons previous. Fig. 9 (Plate IV). The young pycnidium forms immediately underneath the layer of cork of the last annual ring of bark. Fig. 12 (Plate V). As it increases in size it lifts up this cork layer and the larger portion of the pycnidium is to be found on the outside.

On the berry the stroma develops in the hypodermal parenchyma

immediately beneath the epidermis and distorted parenchyma cells are frequently included in it. With the enlargement of the pycnidium the underlying cortical tissue is compressed somewhat, giving increased area within the collapsing berry and the epidermis and cuticle are lifted so that the pycnidium breaks through and develops on the outside to approximately the same extent that it does inside. Fig. 11 (Plate V). The pycnidia on the woody parts are to be found in greatest abundance in early spring. After the June rains only the base of the pycnidium remains and later the cavity in the tissue occupied by the pycnidium is the only visible evidence of this stage.

Canes which are severely infected the previous season often develop great quantities of the pycnidia, while occasionally pycnidia are developed on the current season's growth. In a vineyard where lightning had run the length of the wires of the trellis a great many shoots were damaged and many of the internodes rendered pithless.[3] On such shoots pycnidia of the fungus were found abundantly. Some of these shoots showed the typical black lesions of the disease as did shoots on neighboring vines in other rows, but the pycnidia were developed abundantly and without regard to the occurrence of lesions. The writer would be inclined to interpret the condition illustrated by Selby and Van Hook (1907) in the same way.

On July 12, 1909, a green shoot was found bearing mature pycnidia. This is the only instance of such a condition ever noted, except, of course, that the pycnidia develop abundantly on the green or ripening fruit.

The pycnidium (Fig. 10—Plate V), which is dull black externally, is occasionally a simple flask-shaped body. Usually, however, the inner walls are convoluted and sometimes so much so that there is an appearance of several pycnidia united in a common stroma of fungous tissue (Fig. 12—Plate V). The walls of these chambers are densely lined with a basidial layer of conidiophores from the ends of which the spores are abstricted. Interspersed among the conidiophores there are usually other conidiophore-like bodies bearing

[3] Sometime prior to 1905, Professor Whetzel received specimens of a diseased vine from a vineyardist near Hammondsport, N. Y. An organism was isolated and carried in culture for a long time under the label "pithless cane fungus." Unfortunately the culture finally died out and was discarded. There seems to be no specimen preserved, but from having made numerous test tube transfers of the organism, the writer is of the opinion that this was the dead-arm fungus.

at their tips long, slender, curved bodies which the writer in his former bulletin called paraphyses. This name was used simply because other writers have referred to similar bodies in other species of Fusicoccum as paraphyses. Shear (1911) has chosen to call them scolecospores. In the writer's opinion this is a much better name. The name paraphysis might well be confined to designating the structures occurring between the asci in ascomycetes.

No one seems thus far to have been able to germinate the scolecospores. Whether they should be regarded as a spore form which has ceased to function or whether they are really sterile bodies which serve to separate the somewhat sticky spores may be considered an open question. The scolecospores are always curved towards the ostiolum of the pycnidium and may be found frequently in the pycnidium after all the spores have been discharged. For the most part, however, they seem to ooze from the pycnidium with the pycnospores.

Exudation of spores.— The pycnidium is mature shortly after the bursting of the buds in the spring. If an infected cane or arm is placed in water the pycnidia above the water line will, in the course of a few hours, become prominent on account of the presence of a reddish-yellow ball or long curl of exuded pycnospores. The pycnospores are usually accompanied by a quantity of the scolecospores. If moisture is supplied from the outside as in the case of falling rain the exudation occurs in a similar manner. The actual number of spores that is formed is enormous. A single curl often consists of several thousand spores. When moisture is supplied to the mature pycnidium from below, the spores exude and cling at the mouth of the pycnidium, often drying down there and becoming nearly coriaceous. A drop of water lodging on the spore-stream, however, quickly sets the individual spores free and they float rapidly away.

No further explanation of the discharge of the spores from the pycnidium than that offered in the former bulletin can be given. It would seem that the spores must be surrounded by a mucilaginous substance which expands greatly in the presence of water. Presumably the same substance is active in effecting the rapid movement of individual spores when placed in a drop of water. At any rate they move about much as though a drop of alcohol had been drawn

into the drop of water, setting up unequal tension and producing darting, whirling motions.

As the spores are exuded from the pycnidia, spattering drops of rain carry them to young shoots a few feet away while many are washed to the shoots immediately under the infected arm. As is usually the case, however, the majority of the spores are washed to the ground where they perish. The spores find conditions favorable for germination in the clinging drops of water which persist on the shoots for many hours during periods of continued fog and rain. Ordinarily the temperature is quite low at such times. In 1912, for example, the chief and almost the only infection of the season occurred throughout the Chautauqua and Central Lakes regions on May 28th and 29th. These were days of continuous mist and fog. Foliage of trees and vines was completely enveloped in moisture but the fog was not heavy enough to cause dripping from the foliage except in case of slight puffs of air. It seems quite certain that infection in 1909 occurred on May 28th also. Careful records were being kept in a vineyard at Romulus for the black-rot infection periods. The first black-rot infection of the year occurred on that date and it is believed that most if not all of the infection by Cryptosporella occurred at the same time.

Spore germination.— No attempts have been made to germinate spores of the fungus at the same time that infections were probably taking place under natural conditions. Under more favorable conditions as to temperature it has been possible to germinate the spores, so that they had long germ tubes at the end of 18 to 24 hours. Many attempts have been made to germinate spores on detached leaves and stems in order to study the entrance of the germ tube. Unfortunately no cases have ever been observed.

Meteorological relations.— From what has been said above in regard to the exudation of pycnospores it may be inferred that weather conditions play an important rôle in the dissemination and occurrence of this fungus. It will be recalled that moisture is required for the exudation of spores. Clinging drops of water are necessary for the germination of spores and these drops must persist for a number of hours. Since the major infections of the season are known to occur during the early growth of the vine, that is, during the development of the first three or four internodes, the conditions favorable for infection may be said to be a relatively low tempera-

ture accompanied by rain, preferably gentle rain, followed by mist and fog. The rain is essential for the discharge and distribution of the spores, but gentle rain and fog are more favorable for the lodgment of the spore in a single place where it may germinate. No difficulty has ever been experienced in bringing about germination at various temperatures so that the low temperature usually attendant on infection periods doubtless should be regarded as an incidental meteorological condition. The low temperature actually retards the germination of the spores and thus aids in reducing the amount of infection.

Period of incubation.— After the germ tube of the spore effects an entrance into the interior a considerable period of time elapses before a lesion is apparent. Gregory (1913) records a period of incubation of about 30 days. Inoculations on the green shoots of vines in the greenhouse by Gregory, using a strain isolated from fruit, gave lesions in about a month. Also inoculations of shoots in the greenhouse with spores from a culture kept pure for four years gave lesions in approximately the same length of time. In 1908 when infection was supposed to have occurred on May 28th, lesions were found abundantly on June 26th. In 1909 infection probably occurred on May 28th, while lesions were found abundantly on July 1st. Possibly a search for these a few days earlier would have revealed their presence. In 1912, when infection occurred on May 28th[4] and 29th, unusually abundant infections were apparent on July 3d. How much earlier than this date they appeared is not known. Finally, the writer, as recorded later, inoculated young shoots on May 21, 1913, and found the first well-developed lesions June 23d. It would seem then that approximately 30 days are required before the lesions caused by the fungus are evident.

For the most part only a single period of infection occurs in any given year. This is evident from the fact that the lesions appear almost entirely at the base of the shoots, usually between the first three internodes. It is possible that the tissue of the host is not susceptible after a certain period, as in the case of the black-rot fungus. The more plausible explanation, however, would be that the spores were all matured and discharged at about the same time. For the most part it is impossible to find pycnidia with spores after

[4] It is only a coincidence that prolonged periods of rain and fog should have occurred three different years on this date.

the end of June, although some spores must persist to cause infection on the nearly mature fruits.

In his former bulletin the writer did not regard the infection by spores as seriously as he now does. The suggestion was made there (p. 338) that carrying of diseased material on shears and saw to healthy vines was probably the greatest means of spreading the disease. After more extended observation and experiment it becomes obvious that the importance of shoot infection by means of spores was greatly underestimated. The first intimation of the importance of this method of infection came when a cane taken early in the spring and bearing evident lesions on the peeling bark was placed in a moist chamber for a few days. Great quantities of pycnidia matured and exuded their spores. Further observations along this line confirmed the growing suspicion that the fungus might enter the more permanent wood of the spur, arm or trunk by way of the infected cane tied up for bearing wood. It is not to be expected that every cane which was infected the previous summer will develop the disease but the number that do so is surprisingly large. If only a few spots are produced on the shoot, the resulting cane may bear a crop the succeeding year and be removed before the fungus has had an opportunity to grow down into the more permanent parts. On the other hand, if the infections are numerous and the bark of the shoot broken up into a succession of roughened ridges on the upper side, there is a possibility, in case the cane is saved for bearing wood, that marked symptoms of the disease will develop during the bearing period of the cane, and at all events the probability of the fungus gaining entrance into the arm is greatly increased.

Mycelium.— The mycelium developed from the germinating spores does not differ strikingly from the vegetative portions of many other fungi. The individual strands are hyaline, thin-walled, varying from 1.2 to 2.6 μ in diameter. The growth of the mycelium through the tissue is slow. The truth of this is nowhere better brought out than in inoculation experiments reported in detail elsewhere in this bulletin. Figure 13 (Plate VI) shows what progress was made in a period of 12 months by mycelium and spores of a strain of the fungus (3229) isolated July 2, 1909, from material collected at Fredonia, N. Y., and inoculated into a healthy trunk on July 12, 1909.

It should be borne in mind, however, that this diseased area extends a third of the way around the stem as well as the distance up and down indicated in the photograph. It should also be borne in mind that the fungus was inserted at only one point, whereas in nature it frequently happens that a mycelial development occurs at a dozen or at a hundred different points.

TRANSMISSION OF THE DISEASE THROUGH DISEASED NURSERY STOCK.

The writer suggested in his former bulletin the possibility of transmitting the disease to the vineyards through diseased nursery stock and cited instances where this might have been the case. The complaint frequently mentioned by growers is that vines apparently grow well for the first few years but frequently in their fourth year die for no apparent reason. It would seem quite plausible to expect the disease to be transmitted in such a manner and the occurrence of disease the fourth year in the vineyard would accord very well with the slow development of the fungus. The following experiment was designed to throw some light upon the above consideration.

In July, 1908, numerous infected shoots were marked in a vineyard at Romulus, N. Y. In October these were cut into proper lengths and layered in sand in the greenhouse. On May 4, 1909, the cuttings were taken to Fredonia and planted in a nursery row. Many of the cuttings failed to callus, some were entirely dead, and others half dead. Examination revealed the presence of the pycnidia of Cryptosporella, some of which were practically mature. No record of the number of cuttings that died was made. One hundred sixty-one (161) cuttings were placed in the soil on May 5, 1909. The season was not particularly favorable for the growth of the cuttings. Many developed pycnidia of Cryptosporella during the summer and made a slight growth or failed to put forth any buds at all. On August 17, 1909, there were only 36 plants living and some of these came out so late that there was little hope of their living through the winter. Examination June 26, 1910, showed that thirteen (13) died during the winter, leaving only 23 "roots". A number of the dead vines were examined and the fungus found abundantly on them. Isolation cultures were made from some and the dead-arm fungus obtained without any difficulty. An examination August 29, 1910, showed that

two vines had been broken by accident. Of the twenty-one remaining seven showed spots of the fungus on the shoots, the remaining fourteen appearing healthy. September 29, 1910, the vines were removed to Ithaca and heeled in for the winter. Some vines were lost in some manner so that only fifteen vines were set in the disease garden in the spring of 1911. On November 4, 1911, there were eleven vines in good condition, one very weakly appearing one, and three dead. It is not certain whether the three died from disease or from the excessively cold winter and the late planting, or a combination of these factors. The latter seems most probable. October 12, 1912, the following notes were made on the general condition. Two were struck by the plow and died.

Vine 3, good growth, two shoots infected, one ripe rot berry.
Vine 4, excellent growth, most of the shoots infected.
Vine 5, excellent growth, one arm with tuberculous growth, one arm practically dead.
Vine 6, good growth, most of the shoots apparently infected.
Vine 7, fair growth, severely infected shoots.
Vine 8, fair growth, apparently a few infections on shoots.
Vine 9, good growth, apparently healthy.

A similar lot of material was started in 1909 with the same end in view. The record of growth to date is very similar to that already given and may be chronicled here in the brief notes made from time to time.

1909, July 15, shoots marked in vineyard at Romulus, N. Y.
November 29, cuttings made and buried in a box in the garden.
1910, March 31, 230 cuttings were taken to Fredonia and placed in soil.
June 23, most of the cuttings appear to be alive at this date.
July 17, many of the cuttings dead. Cryptosporella present in abundance and pycnidia oozing spores after 24 hours in a moist chamber. The photograph in Plate IV, C, was obtained from one of these cuttings.
August 29, only 17 plants with leaves; some others appear alive but if leaves were put forth now the vine would probably winterkill.
September 29, vines moved to Ithaca.
1911, May 14, ten vines set in disease garden.
November 14, eight vines now alive in the garden, the other two vines probably died from severe winter and late planting.
1912, October 12, vines in the following condition:
Vine 1, excellent growth, apparently healthy.
Vine 2, fair growth, apparently healthy.
Vine 3, excellent growth, 2 dead arms, some shoots apparently affected.
Vine 4, good growth, apparently healthy.
Vine 5, good growth, apparently healthy.
Vine 6, fair growth, apparently healthy.
Vine 7, good growth, 2 dead arms, 1 shoot infected.
Vine 8, good growth, apparently healthy.

The first lot of cuttings did not have the most favorable conditions for growth, but the second lot was favored in every way. It seems quite evident therefore that the high percentage of mortality must be credited to the dead-arm fungus. If this is the case, the disease in this phase of its development is one of interest primarily to the nurserymen, and the transmission of the disease through nursery stock would appear to be of little consequence. Unfortunately it is now evident that the experiment was not perfectly planned. The cuttings used in both of the experiments were quite badly or even severely infected when they were taken. While the writer is not thoroughly familiar with the practice of nurserymen with respect to making cuttings it would seem that the very short internodes near the base of the cane would not serve particularly well for this purpose and it seems rather doubtful whether badly diseased internodes would be saved for cuttings. In any case such a practice in the future is very unwise for the nurseryman. The experiment would have been of much greater value if canes bearing only one or two spots or possibly half a dozen had been used. Such conditions would have given the cutting every chance to become established and at the same time would prolong the time until the fungus could spread to various parts of the tissue. It is quite probable that such cuttings would make vines that could be sold and which might grow for several years without showing marked evidence of disease.

CONTROL.

ERADICATION.

The method of control described in the former bulletin is still the best and most obvious way of holding this disease in subjection. Since the publication of that bulletin a great many growers in Chautauqua county have given more attention to the prompt removal of diseased wood and the renewal of the vines with new growth from below the surface of the ground. However, certain features are still open for great improvement. Many persons apparently are not yet fully conversant with the fact that the vines which show a dwarfed, crimped and yellow-colored leaf during the early part of the season are affected with the dead-arm disease. This characteristic symptom is of the greatest value in locating vines in the first

stage of the disease. Since these characters show best during June, a time when cultivation is frequent, there is really no excuse for not locating practically every diseased vine in the course of two or three seasons. Such vines should be marked for removal or for special consideration at trimming time. The most convenient method of marking such vines is to carry about a piece of old cotton or linen cloth from which short strips may be torn as occasion demands. These strips should be tied to the affected vines or to the wire. At trimming time they are very conspicuous and are a reminder that the vine needs special attention. Oftentimes the removal of a single arm eradicates the disease. In other cases it will be found that the whole trunk is affected. In case the characteristic discoloration and dry rot is apparent in the main trunk of the vine, the vine should be sawed off at a point some distance below the last indications of rot. In many cases it will be advisable to remove the vine near the ground. This will insure the renewals coming from below the surface. The importance of thus marking and removing early all vines showing symptoms of disease cannot be emphasized too greatly. Some growers make a practice of obtaining some fruit from the diseased vine while a renewal is being trained up. Some years this is a safe thing to do but in other years is a very costly procedure. The great danger lies in the fact that the fungus is almost sure to fruit somewhere on the old dead parts and infect the tender shoot which is saved for the renewal. If all source of infection is removed the renewals are sure to grow healthy and develop rapidly into strong vines.

Every renewal should be inspected carefully sometime during the late summer to see that it has not been infected from some neighboring vine or from chance spores carried in from another source. If a renewal shows any indications of being infected it should be rejected. As a general rule it is well to leave two or three suckers at the base of the stump in order to have a selection from which to tie up.

At the regular trimming time precaution should be made not to leave for bearing wood any canes that show lesions of the disease. At that time the lesions are reddish in color, are slightly elevated, and for the most part are conspicuous. It would be advisable to put up fewer canes than desired rather than to leave affected canes.

The writer feels very strongly that sufficient attention is not given

the vines at trimming time. In many respects the trimming of the vine is the most important operation of the whole year and this is unquestionably true when this disease is present. It is a most unfortunate practice to leave the pruning of the vines to a so-called professional "trimmer", unless the character of his work is well known. It is even more unfortunate to hire the work done by the acre. The writer has seen the work of some professionals which could not be called good pruning and it was very evident that they were either ignorant of or indifferent to methods of eliminating disease.

An eradication experiment.— When the writer began a serious study of this disease in the spring of 1908, and before it was known that the lesions on shoots were in any way connected with the disease, a number of affected vines, approximately 20 years old, were sawed off near the ground and used for cultural and other studies. In most cases a sucker was tied up in place of the vine removed.

As such a method of renewal was being practiced by at least one grower in Chautauqua county a record was made of twenty-three vines thus removed.

Although it was realized before the summer was over that a record of the development of these renewals would mean little in regard to the practicability of such a method of control, owing to the discovery of the fact that the fungus produced infections on the shoots and that some of the shoots tied up were unquestionably infected, it was thought, nevertheless, that a sufficient number would be found free from infection and enough others unquestionably affected to make it worth while to keep a record of development. Accordingly observations and records were made June 8, 1909, August 2, 1910, July 28, 1911, and July 26, 1912, which appear in Table I. Those vines recorded as infected when tied up (condition in 1908) were not examined until June 8, 1909, but at that time unmistakable lesions were evident on the canes. Those vines recorded as questionable did not show lesions and persumably a number of them were healthy. Vines 16 and 18, however, were undoubtedly infected when they were tied up.

Table I (pp. 482–3) shows that renewed vines may be brought into profitable bearing quickly by the renewal system and also shows most strikingly the slowness with which the fungus works. Some of the

suckers tied up were heavily infected and yet few of them died in less than three years.

Spraying.— In regions where black rot is serious the first application of spray for that disease, when the shoots are eight or ten inches long, should prove very effective in preventing new infections on the shoots. Here, as in the case of black rot, it is absolutely essential that the spray be applied before periods of prolonged rain. The method employed in determining these periods in actual vineyard practice are detailed in a number of places, all of which are available to the vineyardist who must spray for black rot.

The black rot disease has rarely caused damage in the Chautauqua belt and the writer knows of only one person who does any spraying with the view of warding off this disease. Therefore, if any early spraying is done it must be with the idea of controlling the infection of the dead-arm fungus on the shoots. Since the majority of growers cannot persuade themselves of the necessity of making the two sprayings required to control the root worm, even though it has been known since the work of Professor Slingerland (1906) that spraying is effective, and in view of the fact that a relatively small number of growers own spray machines it seems nearly useless to recommend this method of control. Nevertheless there are a number of vineyards in which the early application of bordeaux mixture would prove well worth while.

The nurseryman who has a vineyard in connection with his establishment from which to obtain cuttings should make the early applications by all means. If he obtains cuttings from growers he should insist that the vineyard be sprayed, unless a careful inspection reveals the fact that the canes are free from the disease. Such vineyards are relatively scarce. Even though the cost of the cuttings were increased either on account of spraying or inspection, the initial cost would be recompensed by reduced mortality.

In certain years weather conditions are such that practically no infection occurs. The year 1910 was of this character. Such conditions cannot be forecast, however, so that the spraying cannot be omitted.

INFECTION EXPERIMENTS.

In order to test the pathogenicity of this organism and to determine in what manner the fungus might gain entrance to the tissues a number of inoculation experiments have been performed.

TABLE 1.—RECORD OF OBSERVATIONS ON DISEASED VINES RENEWED BY SUCKERS FROM THE BASE.

Some of the suckers were infected, others apparently free from disease.

Vine No.	Condition of old vine.	Where cut off.	Renewal.	Condition 1908.	Condition 1909.	Condition 1910.	Condition 1911	Condition 1912.
1....	Dead	Near ground..	In second year	Infected.....	Apparently healthy.	Apparently healthy.	Small but apparently healthy.	Bearing crop of small clusters. One arm badly diseased.
2 ...	Dead..	Near ground..	Sucker..... ..	Infected.....	Apparently healthy.	Apparently healthy.	Fair size; evidently diseased; narrow area at base dead.	Dead. Pycnidia present. Renewal suckers infected.
3..	Dead	Near ground..	Sucker from beneath ground.	Infected.....	Apparently healthy.	Vine fair size, apparently healthy.	Apparently healthy; stem half dead.	Apparently healthy except longitudinal excrescences.
4....	Dead.....	Near ground..	Sucker.....	?	Broken off; sprout diseased.	Apparently healthy.	Healthy, small..	Healthy, small.
5....	Dead.....	Near ground..	Sucker.....	Infected.....	Apparently healthy.	Apparently healthy.	?	Healthy; good crop.
6...	Dead..	Near ground..	Sucker from beneath ground.	?	Doubtful.. ..	Apparently healthy.	Strong, healthy vine.	Healthy; good crop.
7...	One dead arm, other chlorotic.	Near ground..	Sucker.....	?	Probably infected.	Apparently healthy.	Strong vine, one shoot infected.	Strong vine.
8....	Dead	Near ground..	In second year..	Probably free..	Healthy	Healthy....	Strong vine ..	Strong vine.
9 .	One green shoot, leaves chlorotic.	Near ground.	Sucker	?	Healthy.. ..	Healthy..... ..	Large, vigorous vine.	Gone or else very strong vine.
10..	Chlorotic shoots; no fruit.	Near ground..	Sucker from below ground.	?	Broken off.....	New sucker from above ground.	Healthy.....	Strong vine.

TABLE 1.—RECORD OF OBSERVATIONS ON DISEASED VINES RENEWED BY SUCKERS FROM THE BASE—(*Continued*).

Vine No.	Condition of old vine.	Where cut off.	Renewal.	Condition 1908.	Condition 1909.	Condition 1910.	Condition 1911.	Condition 1912.
11	Dead	Near ground	Sucker one foot above ground	?	Apparently healthy.	Apparently healthy.	Small and weak	Apparently healthy.
12	Chlorotic shoots; no fruit.	Near ground	Two suckers	?	Broken off	Healthy shoots	Fair, vine healthy.	Fair, vine healthy.
13	Chlorotic shoots; no fruit.	Near ground	Sucker	?	Apparently healthy.	Apparently healthy.	Dead.	
14	Dead	Near ground	Healthy suckers in 1910.			Healthy	Large vine	Healthy; good crop.
15	Nearly dead	Near ground	Sucker	?	?	?	?	Healthy and vigorous.
16	Nearly dead	Near ground	Sucker	?	Diseased	Dead.		
17	Dead	Near ground	Sucker from below ground.	Infected	Apparently healthy.	Apparently healthy; shoots infected.	Dead. Suckers all infected.	
18	Dead	Near ground	Sucker from below ground.	?	Apparently healthy.	Apparently healthy; shoots infected.	Dead.	
19	One dead arm	Base of arm					Upper half dead.	Nearly dead.
20	One dead arm	Base of arm			All arms diseased		Small and weak	Dead; suckers infected and chlorotic.
21	Chlorotic	Near ground	Sucker	?	Healthy	Healthy	Healthy; small	Healthy; vigorous.
22	Chlorotic	Near ground	Sucker	Infected	Apparently healthy.	Apparently healthy.	Strong vine	Healthy and vigorous.
23	Slightly diseased.	Near ground	Sucker	?	Healthy	Healthy	Strong vine	Healthy and vigorous.

SPRAYING SPORES ON GREEN PARTS.

The pathogenicity of the fungus has been established by spraying spores on tender shoots (Gregory, 1913). The writer was not successful in his earlier attempts to obtain infections in this way. The failures are readily attributed, however, to the fact that inoculations were not made at the most opportune times. Circumstances did not permit trials in the early stages of new growth. Later in the season great difficulty was experienced, both in 1909 and in 1910, in maintaining spore-laden drops of water on the vines for any appreciable length of time. The wind blowing off Lake Erie in the day and towards the lake at night, dried up the moisture before the spores had an opportunity to germinate. The following paragraph copied verbatim from notes written July 10, 1909, gives an idea of the method of making inoculations and the results obtained:

"An enormous quantity of spores of the dead-arm fungus (3216)[5] from pure culture were placed in boiled rainwater in an atomizer and sprayed on all the vines (38) of row two in the experimental block. There had been a heavy rain and even as the spores were being sprayed on (between 8 and 9 p. m.) the rain was falling. So far as I can find no rain fell after ten o'clock. The wind blew while the spores were being applied and presumably all night. The vines are perfectly dry at seven a. m. this morning."

Similar trials were made in 1909 with various strains of the organism, isolated from different places, on June 22d and 23d, and on July 10th, three different trials were made. In 1910 two trials were made on July 12th, one each on August 18th and 31st, and one on September 4th. The vines sprayed on August 18th were small and were covered with a bell glass.

In one case a sprayed row seemed to show an unusual amount of scattering infections, which is not usual, as well as a greater number of infections than neighboring vines. The number of spots was not sufficient, however, to justify the assumption that the spores sprayed on the vines caused the infections, particularly since the presumed period of incubation was not observed nor recorded and cannot therefore be checked against more definite records.

Inoculations with pure cultures of the fungus (No. 3221, original culture made April 16, 1908) were made May 21, 1913, by suspend-

[5] The figures refer to specimen numbers in the collection of the Department of Plant Pathology, Cornell University.

ing spores in sterile water and spraying them on the young shoots of several small vines. Contemporaneous germination tests of spores in drops of water on glass slides gave 80 to 90 per ct. germination at the end of 20 hours. The plants were entirely covered with bell glasses for 24 hours. Infection was also favored by humid external conditions. Other plants were sprayed with sterile water, but otherwise subjected to the same treatment. They remained healthy. In 30 days (June 20th) lesions became evident on the inoculated plants and when they increased in size some of the stems were completely involved.

July 22d some of the infected shoots were sterilized externally by immersing in mercuric chloride solution 1–1000. Thin shavings of epidermis were removed with a sterile scalpel and bits of the underlying diseased tissue transferred to sterile grape stems in tubes and to potato agar slants. August 5, 1913, the tubes were examined. The Fusicoccum stage of the fungus had developed and was producing spores in six of the ten grape-stem tubes. Two tubes were sterile and one was contaminated. A similar growth of mycelium appeared in five of the eight agar slants, and had the appearance of the dead-arm fungus when grown on potato agar, two tubes remained sterile and one was contaminated.

Two things are of interest in connection with this experiment. (1) The pure culture used for inoculation purposes had been kept alive through successive generations in test tubes for five years. At the end of that time it still retained its virulence as indicated by the abundant infection obtained and by the appearance of lesions after the characteristic period of incubation as noted under natural conditions. (2) The susceptible parts of the vine are limited to the tender, more succulent growth. The infected area on the shoots inoculated was confined to about two internodes, but stem, leaf petiole, leaf veins, tendrils when present, and apparently leaves within this range bore lesions. Older parts were not affected.

In the light of these experiments the failures in the earlier attempts are readily understood. In addition to unfavorable atmospheric conditions it appears that the host had passed the period of susceptibility. The trial of July 12, 1910, was made under fairly favorable conditions in that a heavy rain at 12 m. was followed by calm, cloudy weather which permitted drops to cling to the canes. A quantity

of such drops were collected in a clean atomizer and inoculated with the spores of the Fusicoccum stage of the fungus (2971) from culture. These spores were sprayed on a large number of shoots of Concord vines. Clinging drops of water were then examined and an abundance of spores found. Contemporaneous germination tests on glass slides showed the spores to be viable. No lesions developed on any of the shoots, although the tips were relatively tender.

INOCULATION WITH THE SAW.

First series.— In order to determine the effect on the vines as well as to serve as a check on the experiments about to be described, the trunks of six Worden grapes, eighteen years old, were cut half off with a saw, the cut being made near the ground. Twenty-eight other vines in the same row were treated in a similar manner except that the cuts were not all so deep and that in each case the saw was drawn a few times through a diseased stem and then through the cut previously made. In some cases the saw cuts were made near the arms or in the arms. The object of the experiment was to determine if possible what number of infections occur in this manner. All cuts and inoculations were made July 7, 1909. The infected wood used as a source of inoculation was taken from a vineyard at Prospect, N. Y., the previous day, and by examination with the microscope was known to be infected with the dead-arm fungus.

An examination was made on July 1, 1910, and notes taken on each vine. The vines used as check showed no ill effects of the treatment. The wood was found somewhat discolored for a short distance each way from the cut, in the vine examined, but otherwise seemed to be perfectly sound.

The remaining twenty-eight vines, without exception, showed an exudation of gum about the cut. There was no apparent effect on the vines but three or four were examined and it was found that a dead area extended in each direction a distance of one or two inches.

A second examination was made June 27, 1911. No healing of the wounds had occurred on the check vines. They showed no apparent effect of the treatment and none of them showed gum flow. Many of the inoculated vines still showed gum flow. In a number of cases a sunken pit an inch or more in diameter appeared about the cut. In one vine examined, the wood about the cut was found to be blackened and dead a distance of three inches each way

from the cut. Some cases were found where there was no apparent effect.

On the date of the third examination, July 3, 1912, three of the check vines showed evidence of disease, one apparently affected before the cuts were made. The lesions on the other two were well up in the vine and were removed in pruning.

Of the inoculated vines fifteen showed no apparent effect of the inoculation. Eleven of the remainder showed symptoms of dead-arm disease, some apparently due to the inoculations. One vine was dead and removed and another very sickly but probably not from inoculation.

July 10, 1913, five of the vines serving as checks were in good condition. Of the inoculated vines eleven were recorded as in good condition. Four others seemed in fair condition while the remainder were nearly dead or in very poor condition. The vines were cut off near the ground October 22, 1913, and shipped to Ithaca. October 29th, the inoculated vines were split open and many were found to be decayed. In some cases the discoloration extended over half way through the stem and six inches or more up and down the stem from the original point of inoculation. Attempts were made to remove bits of the discolored tissue under aseptic conditions and transfer them to sterilized grape stems. Of twenty-four such transfers made, nine developed pure cultures of the fungus, ten were contaminated so that it could not be determined whether Cryptosporella was present or not and five remained sterile. It appears from this set of inoculations that infection may occur from the pruning saw, that the fungus does not spread rapidly in the tissue and that discoloration of the woody tissue precedes the advance of the fungus. Examination of the checks failed to reveal the typical discoloration of the dead-arm disease. Some showed only a blackening of the wood as from weathering and others showed the lighter brown decay characteristic of the action of the fungus *Polystictus versicolor*. This only extended a short distance from the original cut.

Second series.— A series of inoculations was made June 22, 1909, in which spores and mycelium of the fungus from a pure culture (3221 isolated May 9, 1909, from exuding spores on 1-year cane) in its second generation were inserted in the cuts. The record for the thirty vines thus inoculated does not differ materially from that above except that most of the vines showed more striking symptoms

of the disease from year to year and more vines were dead or nearly so at the conclusion of the work in 1913. July 19, 1910, one of the vines in this row showed a marked sunken area near the saw cut which was covered with pycnidia. When placed in a moist chamber for a few days spores oozed from the pycnidia and a pure culture of Cryptosporella was readily obtained.

Third series.— On July 12, 1909, thirty-five vines (Worden) were inoculated as above, using spores and mycelium of the fungus from pure culture (3229, isolated from a diseased Concord stem July 1, 1909). On July 1, 1910, all the vines showed a copious flow of gum at the point of inoculation but there was no other apparent effect. June 27, 1911, the sunken areas at the point of inoculation were conspicuous. One vine examined showed dead wood nearly to the heart of the trunk. July 3, 1912, a number of the vines showed marked symptoms of the disease and one vine was entirely dead. July 10, 1913, eleven vines were dead or nearly so, five were in fair condition and eighteen were still apparently healthy. July 19, 1910, one vine was cut off and examined. The extent of the infection is shown in Fig. 13. Direct transfers of diseased tissue to sterile grape stems gave pure cultures of the fungus. A similar isolation was made October 29, 1913, from another of these vines with the same result.

INOCULATION BY INCISION ON SHOOTS.

July 1, 1909, each bearing shoot on thirty vines was inoculated by making a gash with a scalpel near the base and inserting mycelium and spores of the fungus (3216, isolated July 23, 1908, from vine 23 of Table I, and in its fourth generation in culture). July 1, 1910, gumming was observed about the majority of the incisions. One cane examined showed a blackening of the tissue for an inch or more from the point of inoculation. In the case of incisions made as a check a slight blackening may appear later, but does not extend any considerable distance from the original point of incision.

July 10, 1910, the fungus was readily recovered from two of the inoculated canes.

April 26, 1912, a number of the inoculated canes (now arms) were removed and pure cultures of the fungus obtained by direct transfer of diseased tissue. Later in the season, July 3, practically every vine showed marked symptoms of the disease and three of the arms trimmed and tied up were found to be dead. July 10, 1913, thirty-

one dead canes were counted on the vines of this row. Although the vines were partially renewed by tying up canes back of the point of inoculation the row was conspicuous on account of dead canes from the infected arms.

The same organism was inoculated into the canes of twenty-three other Worden vines on July 9, 1909. The photograph shown in Fig. 14, is one of these inoculated canes after fourteen months. Two dead arms were found in 1912, but in general the symptoms were not nearly so marked as in the set of inoculations on shoots.

A culture from a different source (3261) was used for inoculating a number of bearing shoots July 8, 1910. There was no noticeable effect in 1911, but in 1912 a number of arms showed marked symptoms and on one pycnospores were oozing in abundance. In July, 1913, there were a number of dead stubs and canes on the five vines inoculated.

INOCULATION OF ROOTS.

July 18, 1910, the soil was dug away from one side of seven Worden vines and several roots, both large and small, were inoculated through a scalpel wound near the root crown with mycelium and spores of the fungus (3261).

Observations from year to year failed to show any marked effect. In the autumn of 1913, the vines were pulled up and shipped to Ithaca without label. A careful examination was made of all the roots, but the original point of inoculation could not be located with certainty except in one instance. All the roots were examined, but in no case was there any evidence of disease. This bears out frequent observations that the diseased area does not as a rule extend below the surface of the ground, and is a point of considerable importance in control.

BIBLIOGRAPHY.

Bubak, Fr., u. Kosaroff, P. Einige interessante Pflanzen-krankheiten aus Bulgaria. *Centbl. Bakt.* Abt. II, 31:495-502. 1911.

Cavara, F. Intorno alla eziologia di alcune malattie di piante coltivate. *Staz. Sper. Agr. Ital.* 30:487. 1897.

Gregory, C. T. A rot of grapes caused by *Cryptosporella viticola*. *Phytopath.* 3:20-23. Figs. 1-2. 1913.

Reddick, D. Necrosis of the grape vine. Cornell Univ. Agr. Exp. Sta. Bul. 263:323-343. Figs. 41-57. 1909.

Selby, A. D., and Van Hook, J. M. Dying of bearing grape-vines. Ohio Agr. Exp. Sta. Circ. 64: 1–6. Figs. 2. 1907.

Shear, C. L. The ascogenous form of the fungus causing dead-arm of the grape. *Phytopath.* 1: 116–119. Figs 1–5. 1911.

Slingerland, M. V. Final demonstration of the efficiency of a poison spray for controlling the grape root-worm Cornell Univ. Agr. Exp. Sta. Bul. 235: 168–171. 1906.